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THE IMPERIAL SMELTING FURNACE FOR THE SIMULTANEOUS RECOVERY OF LEAD AND ZINC IN DEVELOPING COUNTRIES 1/

by

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Zambia

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B. BARLIN

SYNOPSIS

1. The paper describes the history, geology and metallurgical flowsheet of the Zambia Broken Hill Development Company. The Company is the only mining and metallurgical complex, incorporating an Imperial Smelting Furnace operating in a developing country.

2. The history of the Company is outlined since it's discovery in 1904 and traces the mining and metallurgical development from the crudest zinc calcining operation to the present complex which incorporates the Imperial Smelting Furnace.

3. Since Zambia achieved the status of an Independent Republic in 1964 the emphasis has been on training the local Zambian labour force to higher skills of operation and maintenance. Because of the importance of this aspect in the operation of a sophisticated plant the subject is treated in some detail in order to outline the methods utilised to analyse the jobs necessary to rationalise the labour force, so that adequate training at all levels can be provided.

4. The supply of equipment and materials from sources long distances away from the mine causes sharp rises in Capital outlay which the Company must make available by increasing stores stock holdings.

5. The distribution and sales of finished products, to Customers, who more and more are tending to arise outside of Zambia, is adversely affected by the location of the Company, which is some 1,300 miles by rail from the nearest seaport.

6. Despite all these factors production has increased quite steadily and as long as the conditions for efficient operation continue, the Imperial Smelting Furnace can and will continue to play an ever increasing role in the prosperity of the Company and Country.

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by

B. BARLIN, B.Sc.(Eng.); C.Eng. M.I.M.M.; M.A.I.M.E.

INTRODUCTION

7. The United Nations has, for statistical purposes, defined the main developing areas as Latin America, Africa excluding South Africa and Asia excluding Japan. The Imperial Smelting process for the simultaneous production of Lead and Zinc in a blast furnace is a relatively new process. It was developed by the Imperial Smelting Corporation at Avonmouth in England during the 1950's. Of the eleven furnaces now operating throughout the world, the developing countries boast but one of these plants which is situated at Kabwe in Zambia and operated by the Zambia Broken Hill Development Company. The political implications of it's geographic position in relation to it's neighbours Rhodesia, South Africa and Portuguese East and West Africa have to be taken into consideration when comparisons with other Imperial Smelting Furnace operators are made.

8. Production from the Zambia Broken Hill Development Company represents less than one percent of world production and the country itself consumes less than one percent of it's own production.

9. The problems of operating an Imperial Smelting Complex in a developing country revolve around the labour available for such a sophisticated plant, the transport of specialised stores and equipment to the Mine and the shipping of the greater proportion of metal output to overseas customers in Europe, America, Asia and the Far East.

THE COMPANY AND IT'S HISTORY

10. It is important to bear in mind that the Imperial Smelting Process forms only part of a fully integrated mining and metallurgical complex designed to exploit the mixed lead and zinc sulphide, oxide and silicate minerals contained in the ores. To clearly understand the necessity for the Imperial Smelting Process a brief resumé of the history, geology and metallurgical flowsheet is necessary.1*.

11. The Broken Hill deposits were first discovered in January, 1902 by T.G. Davey, an Australian prospector, and the Rhodesia Broken Hill Development Company Limited was formed in London in November, 1904. The similarity of the deposits to those occurring in Broken Hill, Australia gave the Mine it's name.

12. The orebodies are replacements of the dolomite country rock by lead and zinc minerals. There are three main orebodies all dipping steeply but irregularly to the north. They contain the following ore minerals.

(a) Galena and Zinc Blende (Sphalerite)

(b) Oxidized Lead and Zinc minerals, notably Cerussite, Willemite and Hemimorphite. Many other minerals are also found including some rare minerals such as Hopeite and Tarbuttite.

(c) The complex lead vanadium minerals Descloizite and Vanadanite.

13. At the outcrop the orebodies were more or less completely oxidized. In depth, they commonly contain a core of massive sulphides, oxidized locally to a greater or lesser extent. This core is surrounded by a shell of silicate ore, chiefly Willemite. The irregularity that characterizes the shape of the orebodies applies equally to their mineral content, making ore reserve calculations and the maintenance of a balanced feed to the metallurgical plants problems of some magnitude.

14. High grade silicate ores were first mined and calcined in primitive furnaces for export, but in 1907 shipments were discontinued due to the uneconomic relationship of railage rates to selling price. (The railway reached Broken Hill only in 1906).

15. It was then realised that a mine so remote from centres of consumption must produce the finished metal to be profitable.

16. In June, 1915 a small lead blast furnace for the treatment of oxidized lead ores was blown in, and with the installation of two other furnaces lead production totalled 4,780 long tons by the end of 1917. In the meantime, investigation of the zinc recovery problems was continued and intensified, culminating in the commissioning of an electrolytic zinc plant in 1928 for the recovery of zinc from the silicates. Power requirements were met by the construction of the Mulungushi River Hydro Electric Power Station 1925.

17. In 1937 the Anglo American Corporation were appointed managers and work was started on underground mining and dewatering of the mine.

18. In 1945 the Lunsemfwa River Power Station was commissioned and a new flotation plant for the concentration of zinc and lead sulphide minerals was started. At the same time a Newnam Hearth Plant was constructed to treat the high grade lead concentrate and a Trail type Flash Roaster was commissioned to roast the sphalerite concentrate to augment the electrolytic zinc plant feed, which up to now consisted of silicate ores alone.

19. In 1953 a new lead blast furnace and sinter plant were commissioned, mainly for the recovery of lead from former waste dumps, in particular leach plant residues. This plant never completely fulfilled it's objectives and after a great deal of trouble was closed down in 1958.

20. At this time however it was becoming increasingly clear that if the life of the mine was not to be seriously jeopardised, it was essential to find a satisfactory answer to the problem of improving

recoveries and of the treatment of growing stocks of high grade oxidized products and other dump materials which were not amenable to treatment by the existing processes. After exhaustive examination it was decided in 1960 to instal the Imperial Smelting Furnace for the simultaneous recovery of lead bullion and zinc metal of Prime Western Grade. This plant was commissioned in 1962.

THE FLOWSHEET

21. The mined ores are hoisted to a primary crushing and washing plant. The -¼ inch fraction is screened out and transported to the Sinter Plant. The +¼ inch portion is treated in a Heavy Media Drum Separator to remove dolomite waste rock. The sink product is crushed, ground and treated in a flotation plant for the recovery of the sulphide minerals. The sphalerite concentrate is roasted in the Flash Roaster and the gases are converted to sulphuric acid in a Lead Chamber Plant.

22. Both the roasted calcine and the flotation tailing which contains approximately 25 percent of oxidized zinc are leached together for the production of electrolytic zinc.

23. The feed materials to the Sinter Plant of the Imperial Smelting Process consist of all the -¼ inch material from the ore hoisted, large tonnages of reclaimed dump materials, all the lead concentrate and such calculated tonnages of zinc concentrate to maintain a minimum of 21 percent lead and 24 percent zinc in the sinter fed to the furnace. Condenser and lead refinery drosses are also circulated to the sinter plant. The only fluxing material added to the charge is pulverised limerock.

24. Final Products include electrolytic zinc (99.95% zinc), Prime Western Grade zinc (98.5% zinc) and High Purity lead (99.99+% lead). Silver and Cadmium metals are also produced as by products and in earlier years Vanadium Pentoxide was also produced.

25. Appendix 1a, 1b, 1c and 1d detail a simplified flowsheet for the metallurgical operation.

THE OPERATION OF THE IMPERIAL SMELTING FURNACE

26. The mechanics of the plant and the principles of the process have been adequately described in numerous publications, 2*. In the Zambia plant of major importance is the successful control of the slagging operation and of the condenser system for zinc vapour, in which molten lead is circulated at approximately 2,000 tons per hour. These functions are largely dependent upon manual operations carried out by well trained and experienced operators.

27. Inattention to detail and slow response to deviations from target conditions can cause immediate difficulties which rapidly escalate to halt production entirely for long periods.

28. There exist in addition the hazards associated with the handling of molten metals and slag, lead rich dusts, and toxic and explosive furnace gases.

29. The feed materials for the furnace are confined to those available from the Broken Hill Mine and are relatively low grade and variable by comparison with those available to the majority of Imperial Smelting Furnace's in other countries, where judicious purchase of suitable ores from a variety of sources is possible. As a result, a high proportion of gangue must be handled, which limits the furnace zinc output rate to a level which compares unfavourably with that achieved elsewhere. All other performance indices are however comparable with those of other licencees of the process.

30. The plant was started up during the era of the now defunct Federation of Rhodesia and Nyasaland and the acquisition of the necessary skills in artisans and operatives was a simple matter as they came from Great Britain, South Africa and the remainder of the Federation. With the advent of Independence in October, 1964, it

became the policy of the Zambian Government, and the Company, to enhance the programme of Zambianisation and hence the training and manning department was reinforced to cater for these needs.

31. While good progress has been made in the training of local labour upto and including the supervisory level of section boss it has not yet been possible to operate without skilled expatriate shift supervision. It is this aspect of the Imperial Smelting Furnace which is of major significance to it's successful operation and is dealt with in greater detail as follows.

MANNING AND TRAINING

32. The operation of a plant with a new process anywhere in the world brings in it's train problems of manning and training. In a developing country these problems are compounded and can vary from, in the worst case, absolutely no pool of experienced Industrial workers, to, at best, a moderate supply of workers with similar or related experience. In Zambia at the time of the commissioning of the Imperial Smelting Furnace in 1961 the Zambia Broken Hill Development Company found itself in a position roughly half way between these extremes.

33. The Broken Hill Mine and Plants are the oldest Industrial Workings in Zambia. Operations for the extraction of lead, zinc, cadmium, silver and, in earlier days, vanadium have been carried on with a variety of processes, continuously since 1904. The plants up to this time had generally been unsophisticated in design, calling for a large body of unskilled workers, a small number of semi-skilled operators and an even smaller quota of skilled or professional managers, process controllers and maintenance personnel. The unskilled work force was drawn from the indigenous population while the Europeans supplied the needs of semi-skilled, skilled and professional grades. All degrees of skill were therefore imported through immigration, and in 1961 the Company had in it's employ

adequate supplies of men at all levels of skill with industrial background. The more sophisticated plant design of the Imperial Smelting Furnace merely altered the prevailing proportions between unskilled, semi-skilled and skilled. Training for all the skilled levels was provided by selecting men of known and proven ability in similar capacities on existing plants and sending these to Swansea and Avonmouth for training. The indigenous unskilled labour force was merely drafted across to fill similar positions on the new plant, though of course in lesser numbers than had heretofor been required. From this labour force a few were selected for training in the operation and tending of the simpler machines which had mechanised the labouring functions. Thus the pattern was preserved and skill requirements would still be sought from outside the country.

34. In 1964 Zambia was granted it's independence with Government in the hands of the local population. The Europeans were now foreigners (or as they soon came to be known 'Expatriates'), no longer to be considered as part of the pool of the nation's resources but merely short term fillers of the country's needs.

35. The Company was now in the self same position as any Company attempting to start business in a foreign country. Thus it had to reshape it's manning structure to enable the local worker to progress in an orderly fashion through all levels of the organisation.

36. The local worker, however, was not capable at that time of supplying the needs through all levels of the Company. It was decided, therefore, that Expatriates would be utilised as 'stop gaps' for essentially technical key jobs in the organisation until such time as men of adequate and equivalent technical knowledge and ability could be recruited or trained locally. In fact in many cases the expatriate operator was utilised as the training officer.

37. A labour survey taken at this time indicated that of the total of 2,000 local workers employed by the Company, approximately 1,200 were illiterate, that is illiterate both in English and their

own tribal language. Of the remainder, the bulk were literate only in their tribal language and only two men at that time had a better than Form II (Standard VII) level of education. Further, it was clearly illustrated that the prevailing manning and wage structure with it's grouping of almost the entire local labour force into six main wage/job categories had led to a frozen structure with little or no progressions through the groups. Even recruitment at this time had been absorbed into this thinking and vacancies in any group were filled direct from the recruiting line; thus preventing any movement up through the ranks. (Appendix 2A)

38. With this situation prevailing a conversion, to alter the Manning Structure based on the 'old' principles to the Structure envisaged in the 'New Manning Structure', had now to be contemplated. (Appendix 2B)

39. Training, therefore, had the multiple task of correcting the past position and supplying future needs, and the following terms of reference were laid down:

(a) The Training Department shall analyse and determine work standards, train men to these standards and implement systems to ensure the maintenance of these standards.

(b) Unlike the previous practice all present incumbents will be considered eligible for and receive equal opportunity to be trained in the 'New Jobs'.

(c) No 'present incumbent' employee will be demoted to a lower status of pay should he fail to measure up to the new standards set, but will be carried as an incumbent for pay purposes even should he 'slip down the ladder' in the actual job he ultimately takes as a permanent posting in the New Structure.

40. To resolve the situation in the Metallurgical Departments, job descriptions were prepared of all the jobs appearing in the New Structure. Job Evaluation for wage grading was achieved by the use of a factor comparison manual with points awarded per degree in each factor.

41. The factors evaluated included Education, initative and responsibility, skill and dexterity, and the working ability and conditions.

42. From the job description a breakdown of the components of each factor of the jobs was made. Some components are common to all the jobs; some common to certain of jobs and so on up the scale. Thus it was a fairly simple matter to group these components into a series of courses; 'Basic' for those components common to all, 'Secondary' for all those components incorporated in all the lowest ranges of 'semi-skilled' operations and machine tending, 'Tertiary' for the next range up and 'Specialist' for the individual sectional operational jobs. Thus evolved a system of 'Layered' training, starting from the bottom and working up the Structure. Each succeeding course 'skimming the cream' of the personnel of the proceeding course and building on the foundation already laid. In one operation therefore, the manning structure was converted layer by layer, the best men for each job were found and ear-marked, and each individual kept progressing till the limits of his potential had been met; promotion routes were established and trained men were made ready in each layer to take over jobs 'above' as and when vacancies occurred. Finally every man was trained for at least the job he was holding and duplication of training in training for different jobs was eliminated.

43. To resolve the Engineering Maintenance problem an analysis by trades of the components of skill acquired by an Artisan in the five years of his apprenticeship training was made. It was then determined what parts, and how much, of this could be taught in three months of intensive workshop classroom training followed by three months closely supervised 'on job' training. The skills thus

acquired were formalised as being those of a Mechanic Grade III. Between this, the lowest level of tool using skill, and full artisan skills three further grades of Mechanic were established, namely Mechanic Grade II, Mechanic Grade I and Leading Mechanic. Each grade in each trade, being clearly defined with a job outline and standards set by trade tests. These job outlines and trade tests were eventually collected from all companies in the Mining Industry, standardised and published as the Mechanic Training Manual for the Zambian Mining Industry. But to continue at Broken Hill, Job Cards and Planned Maintenance Routines covering a three to six month period were scrutinised and it was established what proportion of each trade's work could in fact be carried out by the Mechanic Grade III class of worker. The results were often startling. For example it was found that of the total work called for from each trade the following proportions did not require greater skill than that supplied by this class of worker.

Boilermaking	± 60%
Fitting	± 55%
Electrical	± 30%
Carpentry	± 90%
Leadburning	± 90%
Plumbing and Sheet Metal Work	± 90%

44. Thus from these figures it was possible to revise the establishment of the Maintenance Section to incorporate Mechanics and reduce Artisans. By placing the Mechanics in crews under the supervision of Artisans, who were now regarded as Assistant Foremen, it was possible to ensure adequate supervision of the Mechanics, the maintenance of their acquired skills and instant availability to the Mechanics and the Plant of the Assistant Foremen's higher skills and instruction. The actual training programme followed

a similar pattern to that of the Metallurgical Department. With the entire local labour force in Engineering coming into a basic course from which selections for the Mechanic Grade III course could be made.

45. Without going into a great deal of detail many difficulties were experienced but all can be said to be attributed to two main factors - language and environment.

46. To deal with language first - no one local language can be used because there are too many of them, and although many Zambians understand either Bemba or Chinyanja it is not usual to find an understanding of both. Further none of these languages are adequate for expressing technical industrial or scientific subject matter. For example, in the local language there is only one word (translated 'smoke') to cover gas, vapour, steam, smoke or fume. The problem of translating even a laymen's guide to vaporisation of zinc and it's condensation in the condenser with a rough outline of the chemical re-actions taking place becomes insuperable. We might get "The Zinc" rock meets the "coke" smoke, and becomes "zinc" smoke and carbon monoxide smoke, etc., etc.

47. It should be noted that because of the many language difficulties the Zambian Government made English the official language of the country. English because it was formerly an English Colony, but any modern language in use in an Industrial Scientific environment would serve.

48. The problem of environment is of major importance. The majority of the people still lead an agrarian life, with a subsistence economy, utilising the simplest tools and techniques. Before the arrival of the 'European' there was virtually no contact with even the simplest of modern technology. Schooling for all classes of the population has been considerably extended by the Zambian Government, but progress in the Technologies cannot be greater than the capacity of the student to absorb such education. Sciences, such as chemistry and electricity can be accepted on

faith but not with complete understanding (speaking now of the bulk of the population and their work place). To ask a man who has spent 19 of his 23 years in a peasant community (even if he has received a few years of schooling in his village) to understand the purpose of a fuse in an electrical circuit is to stretch his credulity to breaking point.

49. The result is that for any training schemes to be effective there has to be a supporting system of pure education. Initially to provide literacy and ability in both English and Arithmetic, and as men progress adding Mathmatics, Physics and Chemistry, all at basic principle level. This education has to be provided before, during and after job training and is in addition to the job theory such as Technical Drawing, Workshops, Calculating, strength of materials, Bookkeeping, etc. The purpose is to prepare the trainee to be able to understand the instruction he is about to undergo, to provide him with fringe and background knowledge while he is being trained and enlarge his grasp of the concepts he is utilising after he has been posted.

50. The results achieved are best illustrated graphically. Appendix 3 shows the changing pattern of Zambian employment. In the operative grades in 1963 about half of the Zambian employees were labourers and helpers and the other half only semi-skilled, whereas in 1968 some supervisory and skilled categories appear at the expense of the labourer. A similar pattern is illustrated in the maintenance field where a large increase in the number of mechanics appears at the expense of the helper class.

51. Appendix 4 is more significant in that the total expatriate operating and maintenance staff was 45 in 1963 (in the Imperial Smelting Furnace Plant); at the end of 1968 this total had been reduced to 23 by training. The Zambian labour force was increased from 113 in 1963 to 160 in 1968.

ENGINEERING

52. Because of the nature of the process, a fairly high proportion of automatic control equipment and instrumentation is necessary for control purposes. In addition, special materials such as alloy and refractories are used to withstand the high temperatures and the violent action and extreme conditions within the furnace and condenser systems. Practically every section of the plant is inter-dependent, each unit following the other with very little standby equipment, so that in order to be economic a very high plant availability must be realised.

53. The maintenance crews carry out all normal running maintenance. However, since most of the equipment is mostly in operation it is necessary to shut the plant down completely at regular intervals (between ten - fourteen days) for cleaning purposes and to carry out any preplanned maintenance or modification desired. Depending on the nature of such work, it is more than often necessary to augment the labour force by transferring labour from other sections of the plant.

54. At approximately yearly intervals a furnace shaft cleanout and major rebuilding of the furnace is carried out. The shutdown periods can vary between fourteen and thirty days depending on the nature and extent of the work to be carried out and again the artisan labour force must be increased. In developed countries the source of such extra labour is from contractors who specialise in the type of work.

55. In Zambia the company must provide this labour, which is done from the other plants, but on these occasions the requirements cannot always be met and shut down labour remains a problem. However, by training mechanics to increase their skills, it is hoped that the problem can be overcome in time.

56. Because the process is relatively new the degree to which the incorporation of new ideas by modification takes place is

naturally greater than in any established process. The company therefore, also provides for Design and Professional Engineering services.

57. Plant availability being of paremount importance to the economic operation of the Imperial Smelting Process, the services of well equipped engineering workshops is essential. There are, therefore, a boilershop, machine shop, carpenter shop, electrical shop, transport garage and foundry capable of undertaking work at very short notice. These workshops are staffed by some forty-nine artisans and fifty-four Zambian mechanics, of which some forty percent is devoted to work for the Imperial Smelting Furnace.

STORES AND MATERIAL SUPPLIES

58. The supply of stores, equipment and materials, presents one of the major difficulties faced by a company operating fairly sophisticated plants many thousands of miles from the source of supply.

59. During the existence of the Federation of Rhodesia and Nyasaland, most of Zambia's requirements were met quickly and cheaply from Rhodesia and South Africa. Since Rhodesia's U.D.I. however, and Zambia's desire to divorce herself from dependence on her Southern neighbours, alternative sources of supply have had to be found. In the transition period, therefore, it has become absolutely essential to reset realistically levels of stores held on the mine with a sufficient margin to cover emergencies. The immediate effect of this was the increase in the cost of stores stock holdings by some twenty-seven percent to cover the resultant much longer delivery periods.

METAL SALES

60. Zinc

Between 1962 and 1964 sales were shared equally between Central/South African Markets and Overseas. The additional demand

by the South African market in 1965, due to the increase in the South African Stockpile, declined until October, 1968, when the South African Government banned the importation of zinc by rail. Ninety percent of our production will be sold overseas in 1969.

61. Sales Price between 1962 and August 1964 was based on the London Metal Exchange Prices. Sales have been at Producer Price since August, 1964 and have declined from K220 per long ton in September, 1964, to K196 per long ton in 1968 due mainly to world supply position. (one kwacha = $1.4).

62. Metal is sold f.o.r. Kabwe for Central and South African Customers and c.i.f. for Overseas Customers. Any divergence between sales in African and Overseas, reflecting an increase in the latter, does incur greater costs due to Realisation Charges on c.i.f. sales. This has now become fact due to the South African withdrawal and Realisation Costs will be increased considerably in 1969.

63. Lead

In 1962 the majority of sales were to South Africa but South African Sales decreased in 1963 in spite of the advent of consignment stocks provided for the benefit of South African Customers.

64. The Sales Price is based on the London Metal Exchange Prices - either the daily price or the average cash sellers price for the month preceeding shipment.

65. The London Metal Exchange Price for lead rose from K100 per long ton in August, 1964 to K312 per long ton in February, 1965. This price fell away to K164 in 1967 and although this reached a peak of K181 in December, 1968, the average for 1968 was K175.

66. As in the case of zinc the sales mix of African Sales (f.o.r.) and Overseas (c.i.f.) is important as any increase in Overseas Sales decreases the profit margin.

67. The fact of Zambia being some 1,300 miles from the nearest ports of Beira and Lourenco Marques in Portuguese East Africa

presents many problems, particularly as all traffic has to pass through Rhodesia.

68. In travelling through three different countries three railway companies are involved, each presenting it's own problems of language, currency and difficulties with Rolling Stock.

69. The major difficulty arose following U.D.I. in Rhodesia and the break-up of the Rhodesia Railways. All cargo travelling south is paid for in advance and trucks are exchanged one-for-one at the Rhodesian border. This leads to congestion at Livingstone when trucks on either side of the border are not available for exchange.

70. Following the formation of a separate Zambia Railways difficulties were encountered due to the shortage of Rolling Stock workshops and experienced staff. All locomotive repairs had to be carried out in Rhodesia and at one period in 1968 there was a dearth of locomotives in Zambia due to a series of breakdowns.

71. For these reasons it has been exceedingly difficult to maintain any continuity with regard to the despatch of goods from the Mine. In order to compensate for this, it was necessary to increase consignment stocks for South African customers and increase our Stockpiles at both Beira and Lourenco Marques. The latter resulted in an increase of the Port Stockpile in 1968 by 10,000 tons. Not only are Realisation Costs increased, due to Port Storage Charges, but there is also the considerable loss in Revenue from unsold stock.

72. Appendix 5 demonstrates the changing pattern of metal sales. Of the total metal produced, greater proportions are being sold outside of Africa. In earlier years the major customer was South Africa, but since production of their own zinc requirements in 1969, more sales have been directed overseas.

CONCLUSION

73. There are many plants constructed and successfully operated in remote parts of the world. The operation of the Imperial Smelting Furnace in Zambia is little different, and given the right climate in terms of skills and supplies, there is no reason why operations should not continue to improve.

74. Perhaps this latter point is better demonstrated graphically. Appendix 6, shows the gradual increase in metal production since the plant was commissioned.

ACKNOWLEDGEMENTS

75. The Author wishes to thank both the Anglo American Corporation and Imperial Smelting Processes for permission to publish this paper and the Staff of the Zambia Broken Hill Development Company for their assistance in the compilation of the data.

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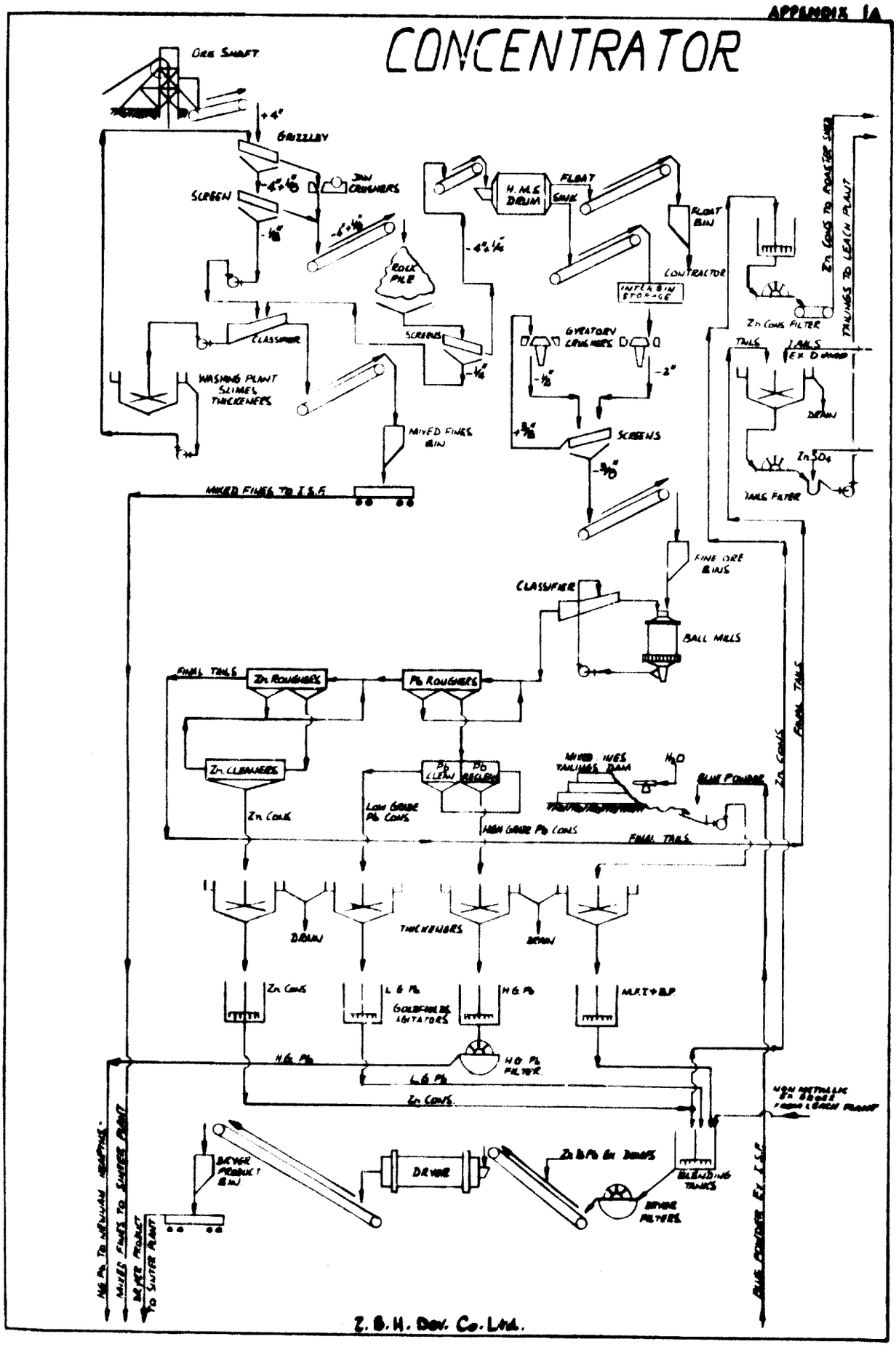
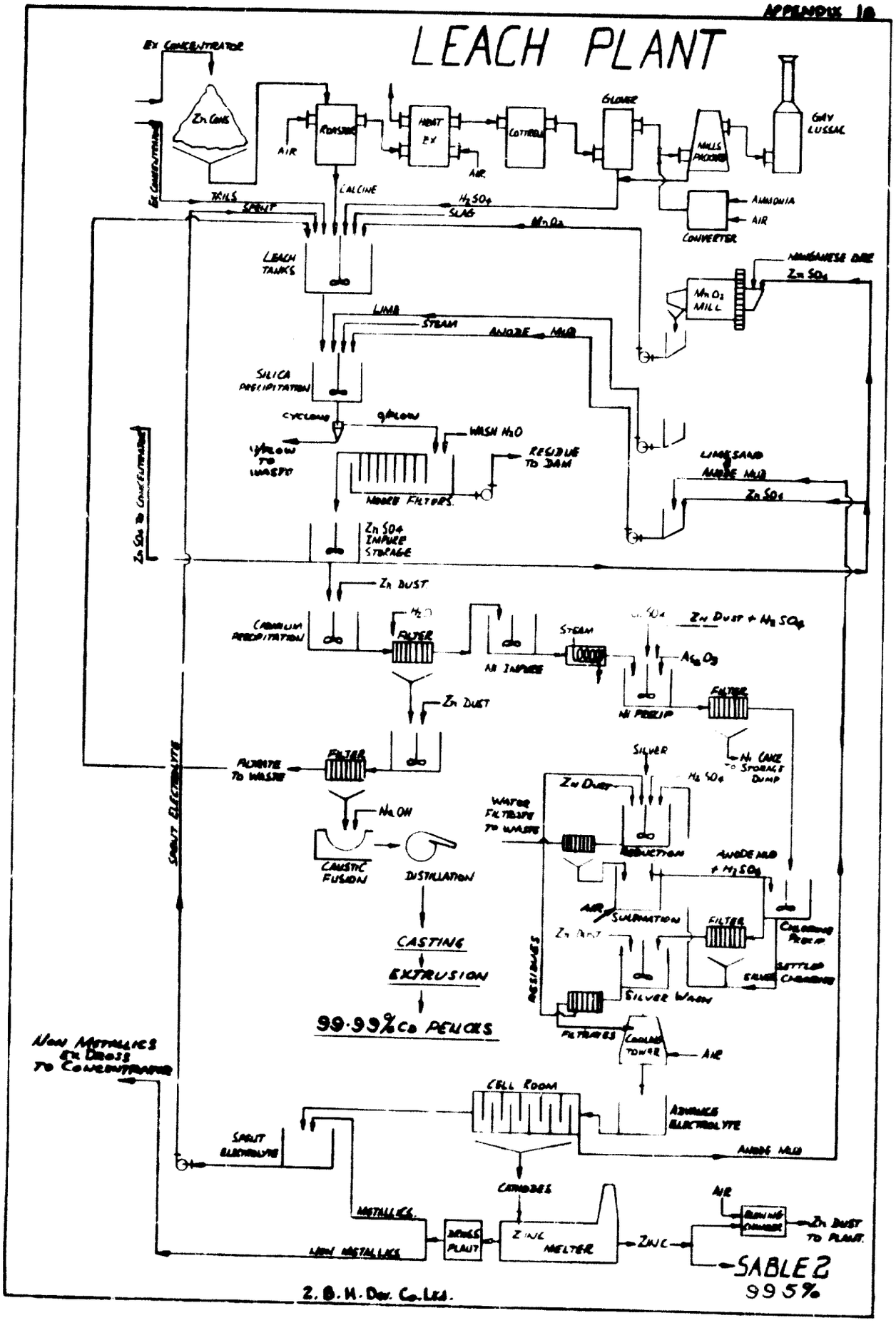
APPENDIX 1A



Z. B. H. Dev. Co. Ltd.

APPENDIX 1B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AIR
ROASTER
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BLOWER
MILLS PACKER
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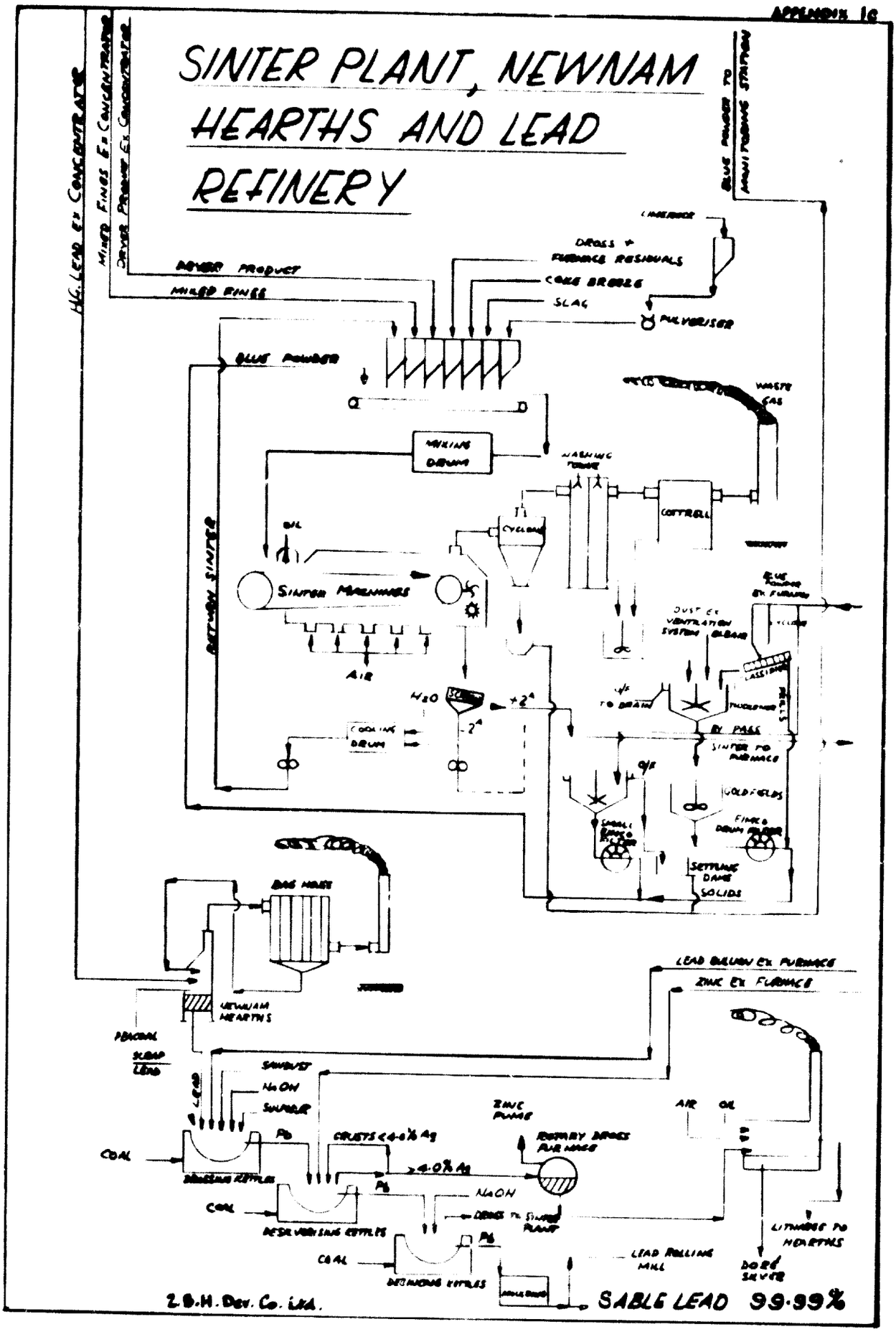
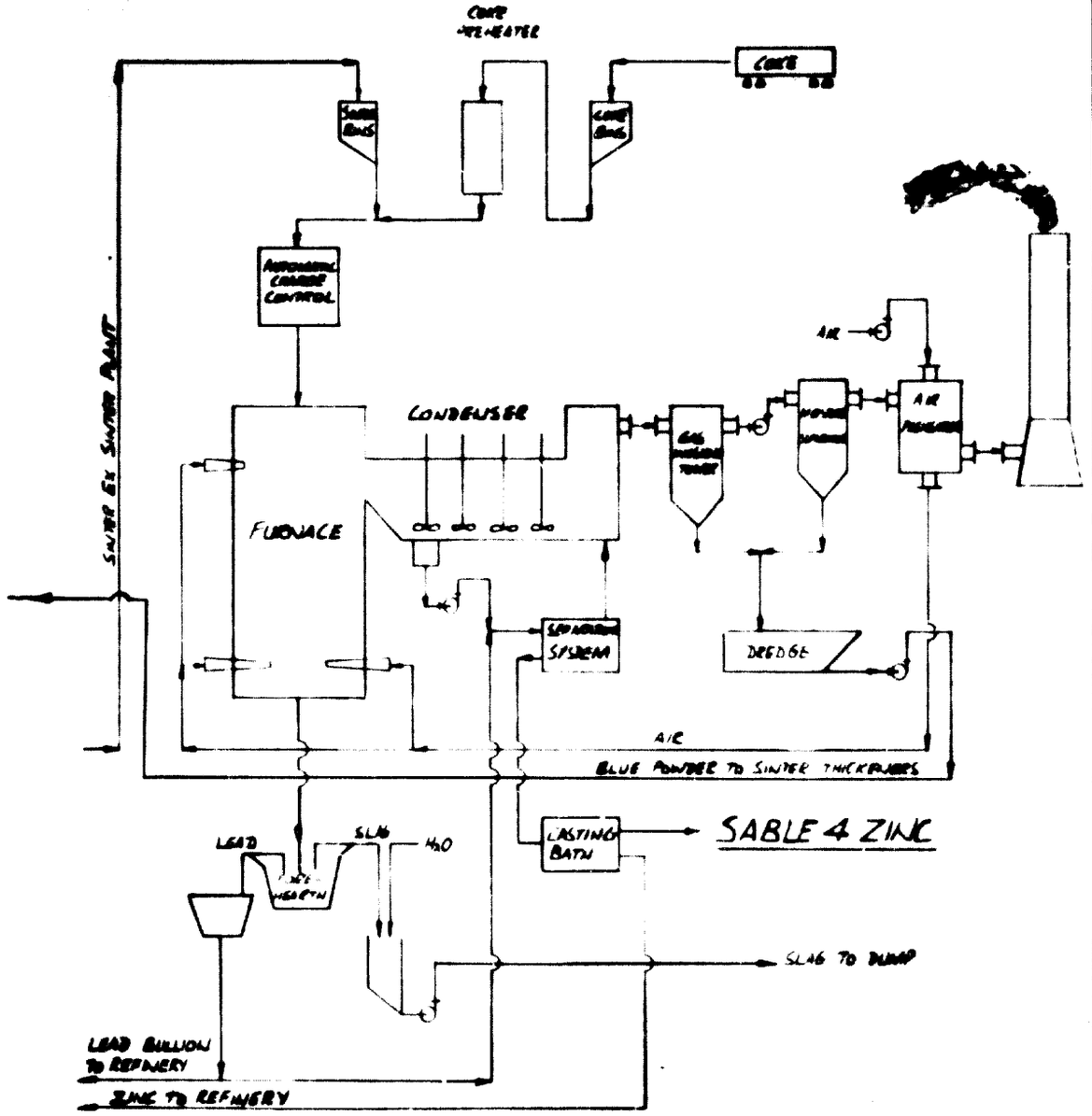
CALCINE
H_2SO_4
SLAG
MnO_2
AMMONIA
AIR
CONVERTER
LEACH TANKS
MANGANESE ORE
$Zn SO_4$
MnO_2 MILL
LIME
STEAM
ANODE MUD
SILICA PRECIPITATION
CYCLONE
WASH H_2O
RESIDUE TO DAM
WASTE
NUTSCH FILTERS
LIME SAND
ANODE MUD
$Zn SO_4$
$Zn SO_4$ IMPURE STORAGE
$Zn SO_4$ TO CONCENTRATOR
Zn DUST
CADMIUM PRECIPITATION
FILTER
STEAM
Ni IMPURE
Zn DUST + H_2SO_4
As_2O_3
Ni PRECIP
FILTRATE TO WASTE
SPENT ELECTROLYTE
$NaOH$
CAUSTIC FUSION
DISTILLATION
CASTING
EXTRUSION
99.99% Cd PELLETS
SILVER
Ni CAKE TO STORAGE DUMP
WASTE FILTRATE TO WASTE
REDUCTION
ANODE MUD + H_2SO_4
AIR
SULPHATION
CHLORINE PRECIP
SETTLED CHLORIDES
SILVER WASH
RESIDUES
FILTRATES
COOLING TOWER
AIR
NON METALLICS Ex DROSS TO CONCENTRATOR
CELL ROOM
ADVANCE ELECTROLYTE
SPENT ELECTROLYTE
ANODE MUD
CATHODES
AIR
METALLICS
NON METALLICS
MELTER
ZINC
Zn DUST TO PLANT
SABLE 2
99.5%
2. B.M. Dev. Co. Ltd.

APPENDIX 16


SINTER PLANT, NEWNAM HEARTHS AND LEAD REFINERY
HG. LEAD EX CONCENTRATOR
MIXED FINES EX CONCENTRATOR
SILVER PRODUCT EX CONCENTRATOR
BLUE POWDER TO ANNEALING STATION
SILVER PRODUCT
MIXED FINES
DROSS & FURNACE RESIDUALS
COKE BREEZE
SLAG
PULVERISER
BLUE POWDER
WASTE GAS
MIXING DRUM
WASHING TOWER
COTTRELL
CYCLONE
RETURN SINTER
SINTER MACHINES
AIR
COOLING DRUM
BY PASS
SINTER TO FURNACE
GOLD FIELDS
SETTLING DAMS SOLIDS
BAG HOUSE
LEAD BULLION EX FURNACE
ZINC EX FURNACE
NEWNHAM HEARTHS
SAWDUST
NaOH
SULPHUR
ZINC FUME
AIR
OIL
COAL
CRUSTS < 4.0% Ag
> 4.0% Ag
REFINERY DROSS AIR MACS
DROSS TO SINTER PLANT
LITHARGE TO HEARTHS
LEAD ROLLING MILL
DORE SILVER
SABLE LEAD 99.99%
E.B.H. Dev. Co. Ltd.

ACCUMULATOR

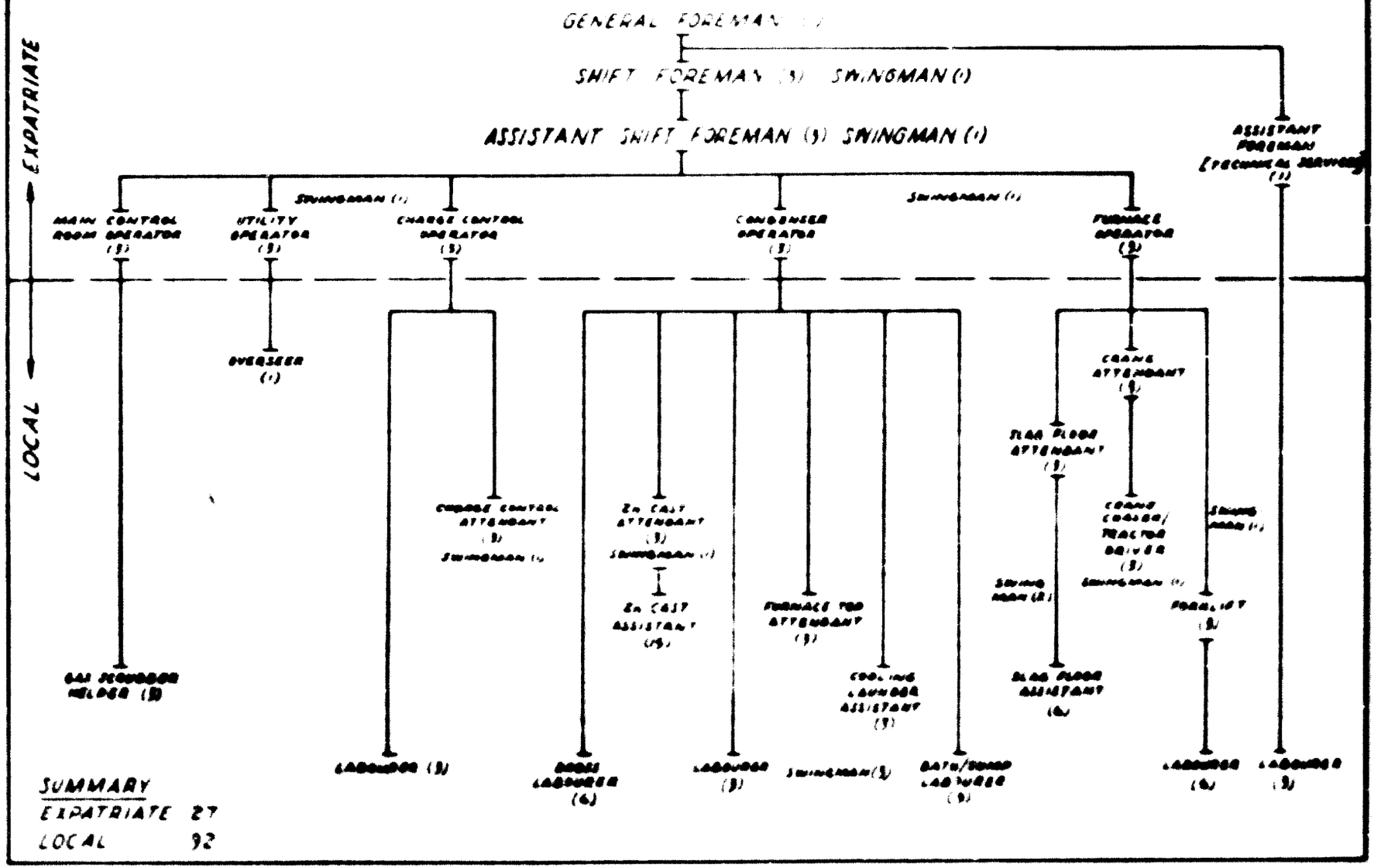
IMPERIAL SMELTING FURNACE



APPENDIX 2A

THE IMPERIAL SMELTING FURNACE FOR THE SIMULTANEOUS RECOVERY OF LEAD AND ZINC IN DEVELOPING COUNTRIES
by B BARLIN

LABOUR ORGANISATION 1963



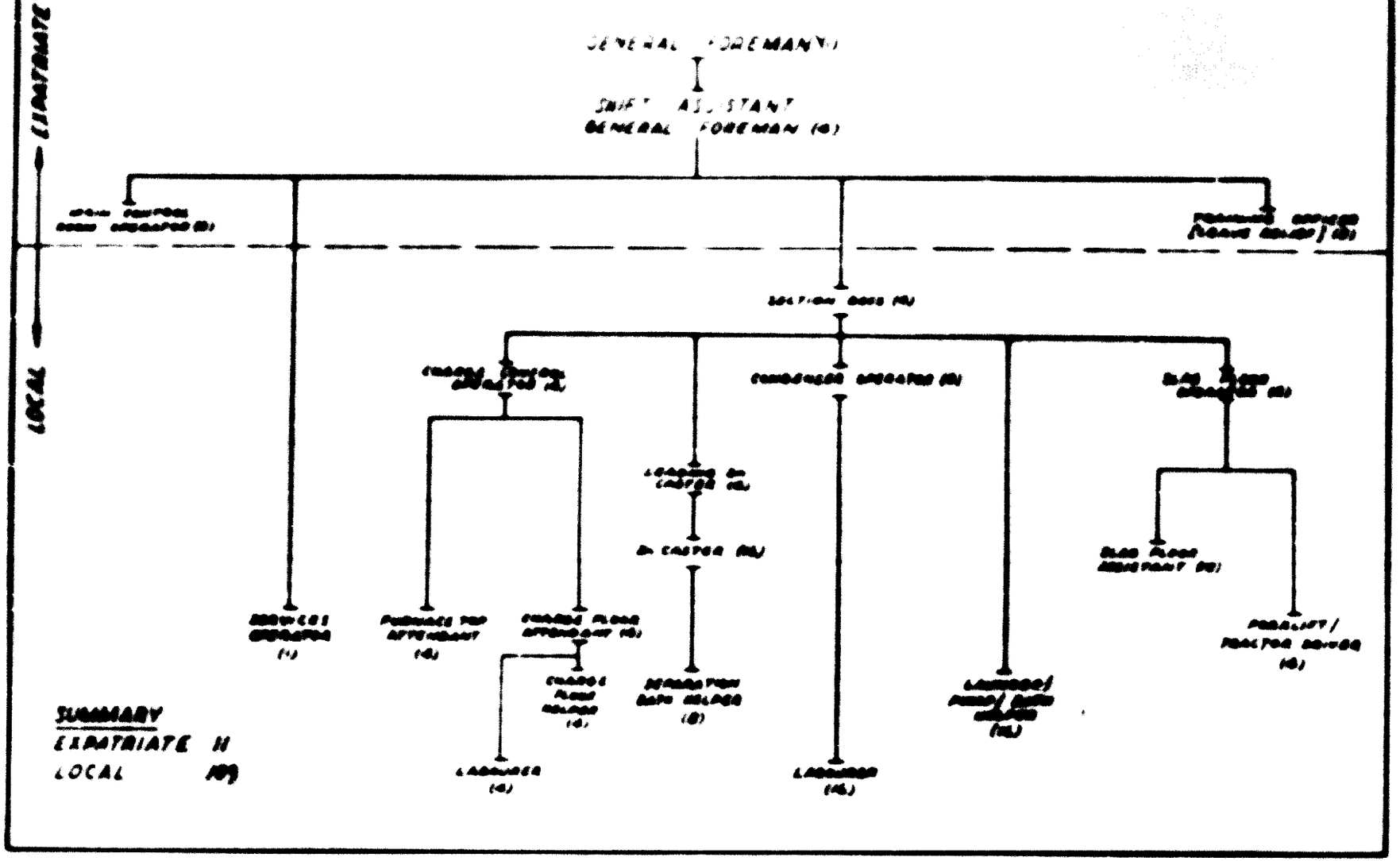
SUMMARY

EXPATRIATE	27
LOCAL	92

THE IMPERIAL SMELTING FURNACE FOR THE SIMULTANEOUS RECOVERY OF LEAD AND ZINC IN DEVELOPING COUNTRIES
by B BARLIN

APPENDIX 8b

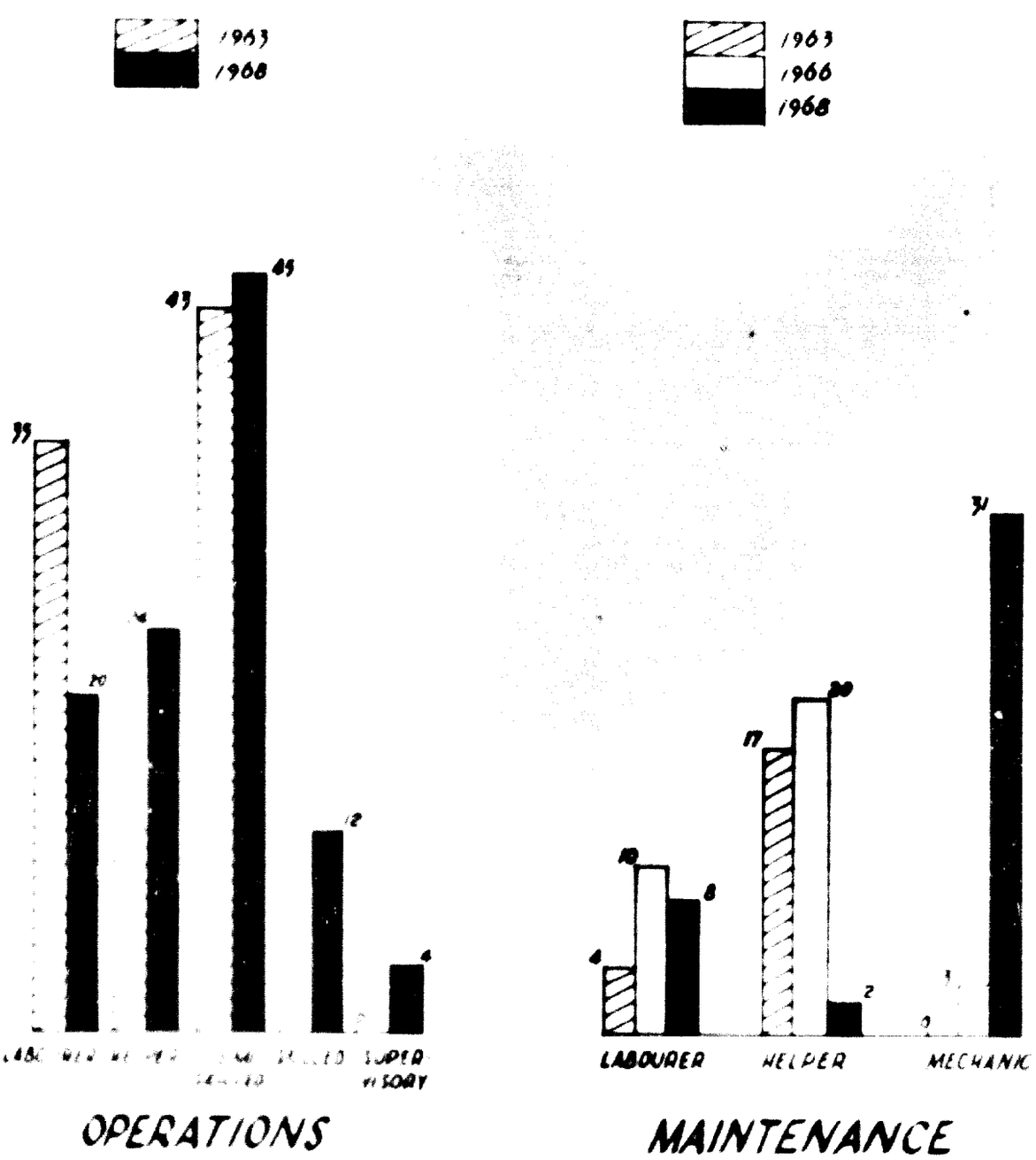
LABOUR ORGANISATION 1968



THE IMPERIAL SMELTING FURNACE FOR THE SIMULTANEOUS RECOVERY OF LEAD AND ZINC IN DEVELOPING COUNTRIES by B. BARLIN.

APPENDIX 3

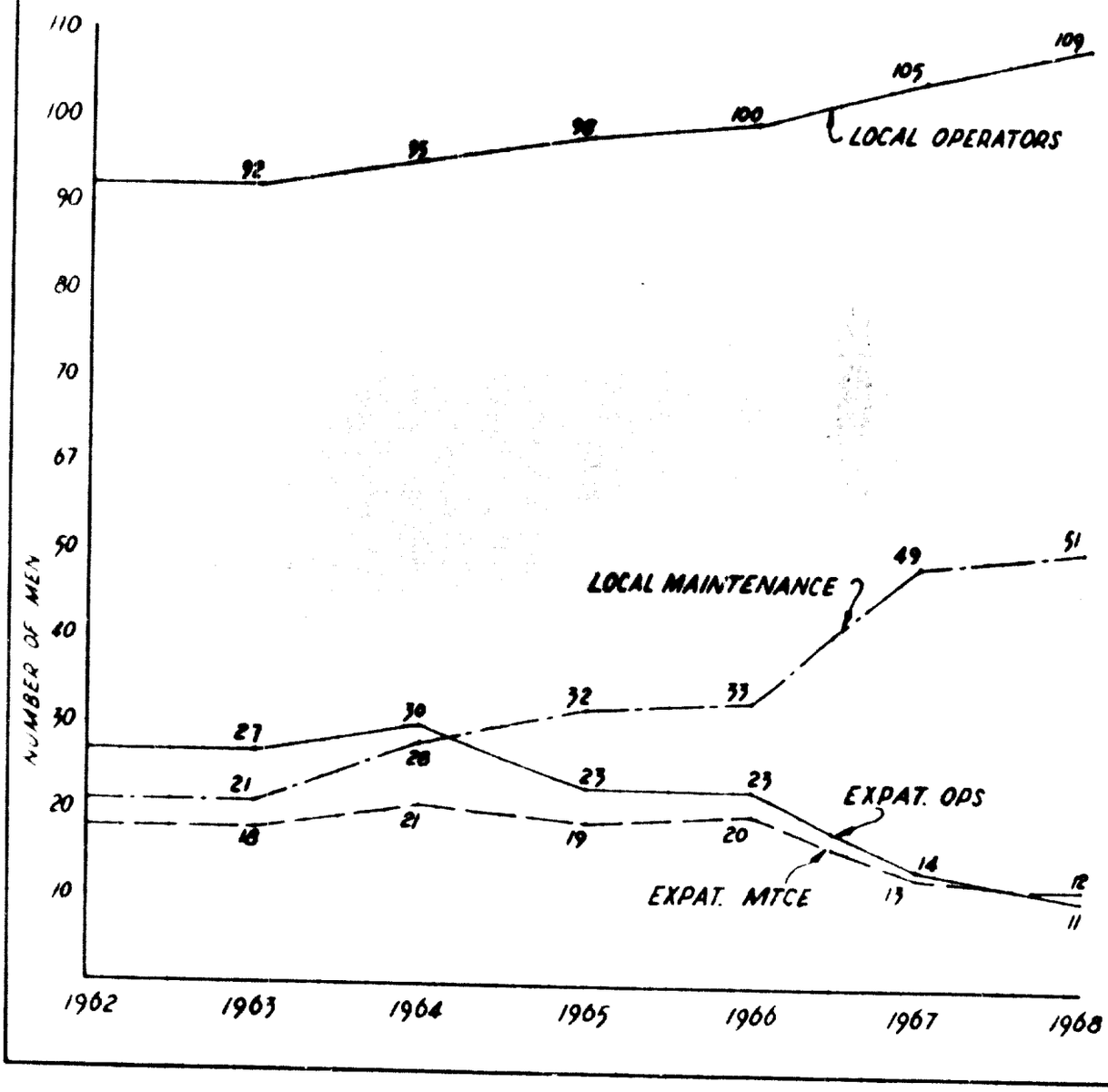
THE CHANGING PATTERN OF ZAMBIAN EMPLOYMENT



THE IMPERIAL SMELTING FURNACE FOR THE SIMULTANEOUS RECOVERY OF LEAD AND ZINC IN DEVELOPING COUNTRIES
by B. BARLIN.

APPENDIX 4

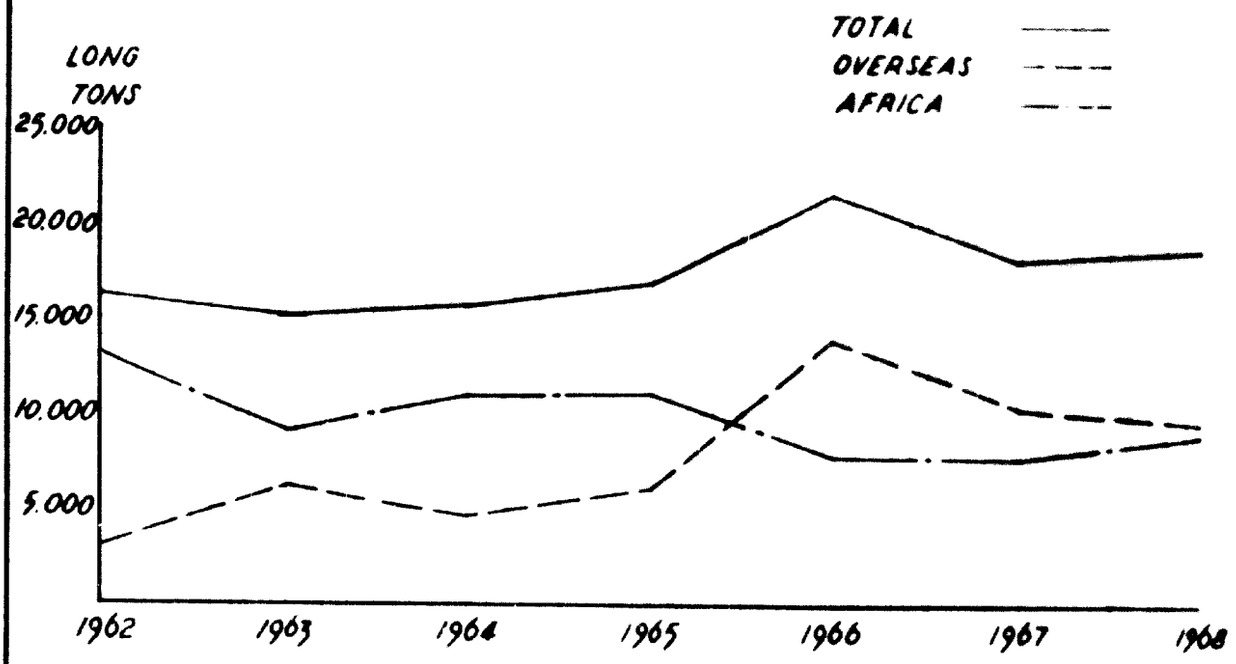
PROGRESS OF ZAMBIANISATION 1963 - 1968



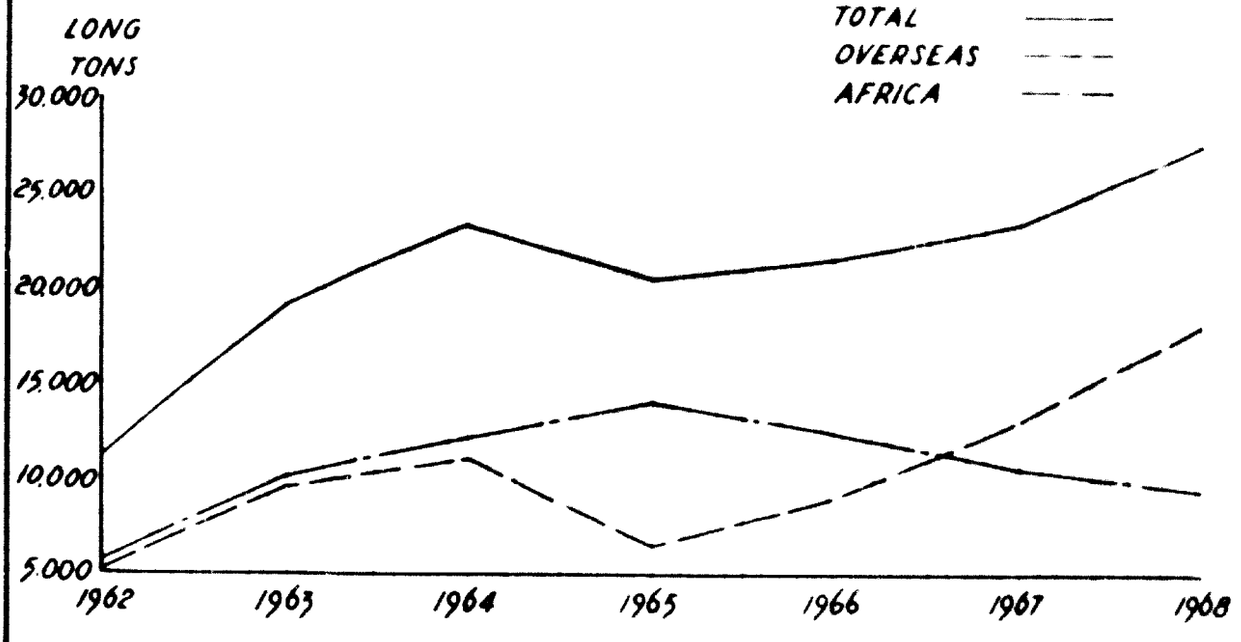
THE IMPERIAL SMELTING FURNACE FOR THE SIMULTANEOUS RECOVERY OF LEAD AND ZINC IN DEVELOPING COUNTRIES
by B. BARLIN

APPENDIX 9

I.S.F SALES TONNAGE SABLE LEAD 99·99+%

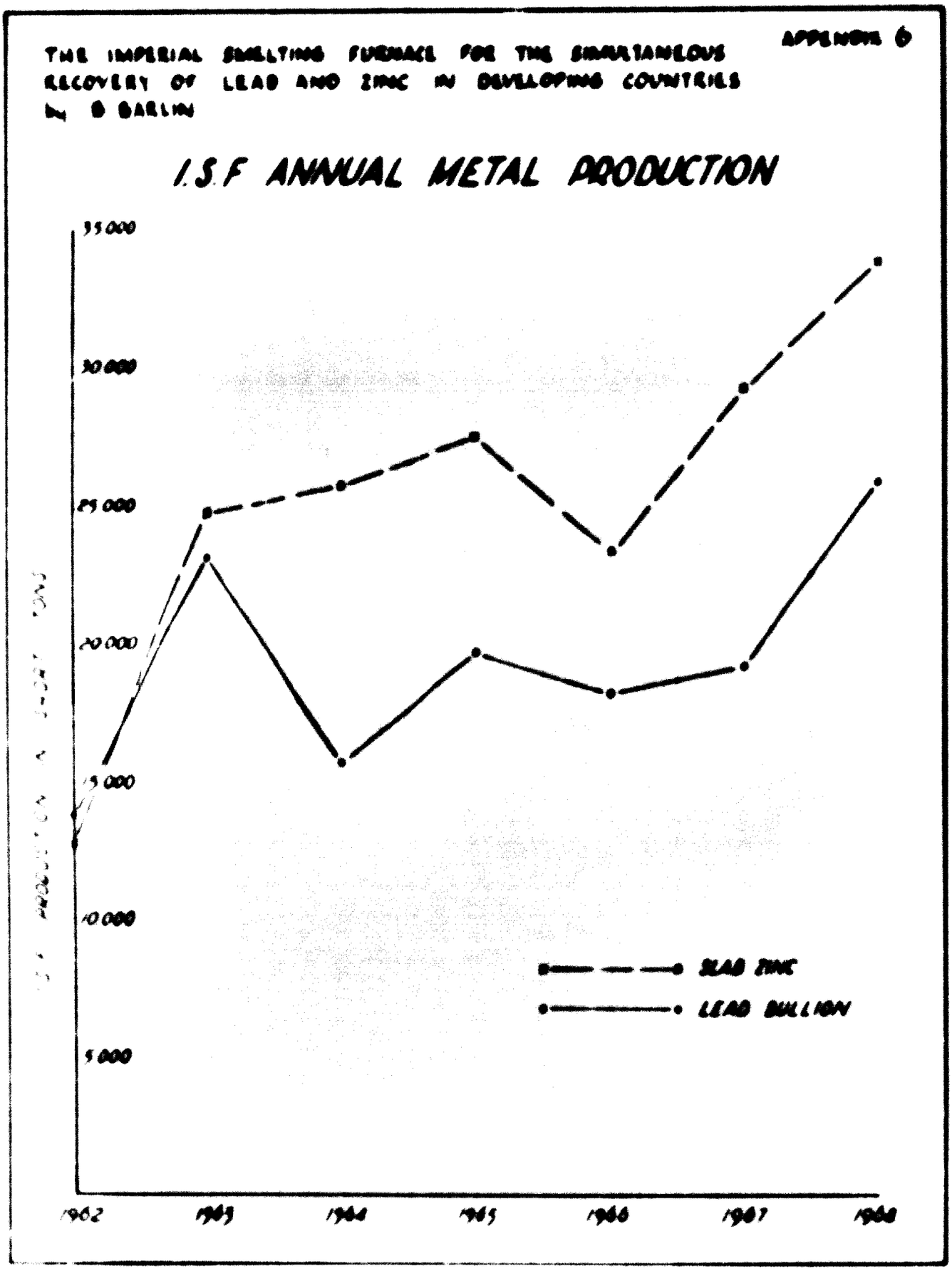


I.S.F SALES TONNAGE SABLE 4 ZINC 98·5+%



APPENDIX 6

THE IMPERIAL SMELTING FURNACE FOR THE SIMULTANEOUS RECOVERY OF LEAD AND ZINC IN DEVELOPING COUNTRIES
by B BARLIN

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